dAb: Interactive Haptic Painting with 3D Virtual Brushes

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UNC Chapel Hill

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dAb != DAB

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Introduction

- Interaction method
- For 2D painting
- Using 3D brush
  - With haptic feedback
  - With deformation
- Palette & paint

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Introduction

- *Interaction method* ►
- For 2D painting
- Using 3D brush
  - With haptic feedback
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Introduction

- Interaction method
- *For 2D painting* ►
- Using 3D brush
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Introduction

- Interaction method
- For 2D painting
- *Using 3D brush* ►
  - With haptic feedback
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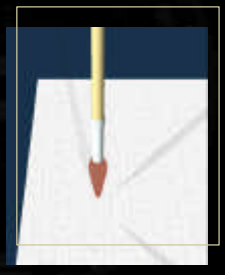

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Introduction

- Interaction method
- For 2D painting
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  - *With haptic feedback*
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PHANToM
SensAble Technologies

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Introduction

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Windows Media

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Introduction

- Interaction method
- For 2D painting
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- *Palette & paint*

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Introduction

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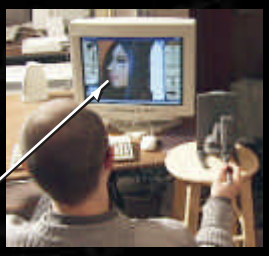
dAb



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Motivation

Capturing the Sight, Touch, Action and Feeling of Painting

- 3D deformable brush *[action]*
- Haptic feedback *[touch]*
- Paint model *[sight]*
- User interface *[action]*

[feeling]

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Painting with dAb

- [video]

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Presentation Overview

- **Previous Work**
- **User Interface**
- **System Organization**
- **System Components**
  - Brush models
  - Force feedback
  - Paint model
- **Results**

Previous Work

- Computer-Generated Painting
- Modeling of Paint
- Modeling of Brushes & Strokes
- User Interface

Previous Work

- Computer-Generated Painting
- Modeling of Paint
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Previous Work

- Computer-Generated Painting
  - **Meier 96, Curtis et al. 97, Hertzmann 98, Litwinowicz 97**
- Modeling of Paint
- Modeling of Brushes & Strokes
- User Interface

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Previous Work

- Computer-Generated Painting
- Modeling of Paint
  - **Curtis et al. 97, Cockshott et al. 92, Hasse & Meyer '92, Kubelka & Munk '31**
- Modeling of Brushes & Strokes
- User Interface

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Previous Work

- Computer-Generated Painting
- Modeling of Paint
- Modeling of Brushes & Strokes
- User Interface

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Previous Work

- Computer-Generated Painting
- Modeling of Paint
- Modeling of Brushes & Strokes
- User Interface

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Previous Work

- Computer-Generated Painting
- Modeling of Paint
- Modeling of Brushes & Strokes
  - **S. Saito et al. 99, Wong et al. 00, Strassmann 86**
- User Interface

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Previous Work

- Computer-Generated Painting
- Modeling of Paint
- Modeling of Brushes & Strokes
- User Interface

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Previous Work

- Computer-Generated Painting
- Modeling of Paint
- Modeling of Brushes & Strokes
- User Interface

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Previous Work

- Computer-Generated Painting
- Modeling of Paint
- Modeling of Brushes & Strokes
- User Interface
  - **A. R. Smith 78, Painter, Z-Brush, Deep Paint**
  - **Hanrahan & Haeberli 90, Agrawala et al. 95**
  - **Johnson et al. 99, Gregory et al. 00**

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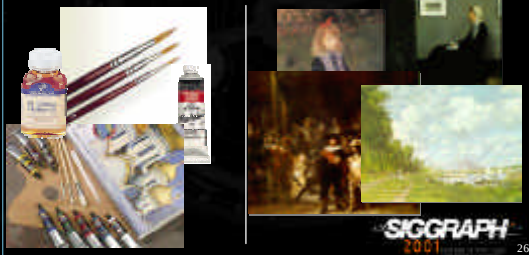
Motivation Revisited

- The *craft* of painting vs. the *art*



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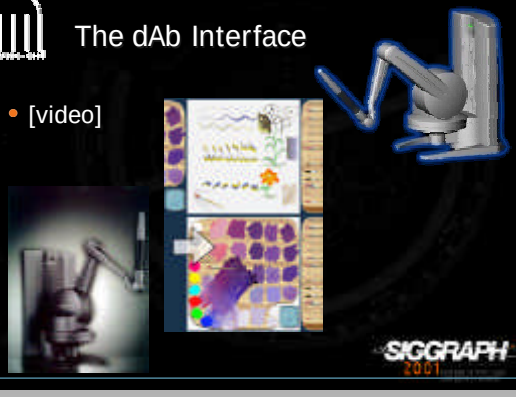
The dAb Interface

- [video]



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NOTE: when giving presentation, click in center to progress animation, click on right edge to advance to next slide!

System Components

- **Brush Model**
- **Haptic Model**
- **Paint Model**

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System Components

- **Brush Model**
- **Haptic Model**
- **Paint Model**

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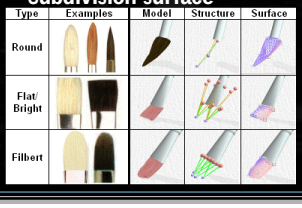
Brush Model

- Design considerations
  - **Interactivity (~30Hz)**
  - **Unconditional stability**
  - **Flexibility**

Type	Examples
Round	
Flat/ Bright	
Filbert	

Brush Model

- Dynamic model
  - **Spring-mass particle system**
- Geometric model
  - **Subdivision surface**



Brush Equations

- **F=ma, or** $\begin{pmatrix} \dot{\mathbf{x}} \\ \dot{\mathbf{v}} \end{pmatrix} = \begin{pmatrix} \mathbf{v} \\ \mathbf{M}^{-1}\mathbf{f} \end{pmatrix}$
- **Semi-Implicit numerical integration (*Desbrun '99*)**

$$\mathbf{f} = \mathbf{f}_c + \mathbf{f}_n$$

Linear force

Non-linear force

$$\begin{pmatrix} \Delta\mathbf{x} \\ \Delta\mathbf{v} \end{pmatrix} = \begin{pmatrix} h(\mathbf{v}_i + \Delta\mathbf{v}) \\ \left(\mathbf{I} - h\frac{\partial \mathbf{f}}{\partial \mathbf{x}}\right)^{-1} h\mathbf{M}^{-1}\mathbf{f}(\mathbf{x}_i) \end{pmatrix}$$

Constant!

Brush Equations

- **Overdamped inertial system**
- **Eliminate explicit damping**
- **Solve F=mv (*Aristotelian*)**

$$\Delta\mathbf{x} = \left(\mathbf{I} - h\frac{\partial \mathbf{f}}{\partial \mathbf{x}}\right)^{-1} h\mathbf{M}^{-1}\mathbf{f}(\mathbf{x}_i)$$

System Components

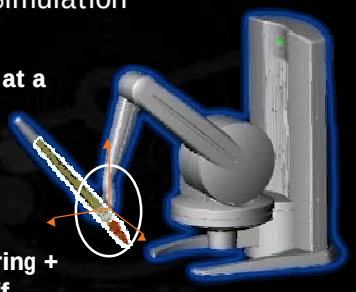
- **Brush Model**
- **Haptic Model**
- **Paint Model**

Haptics

- **Simple model**
- **Designed to run easily at 1kHz**
- **Decoupled from dynamics**
- **Effective for control**

Haptic Simulation

- **Force vector at a point**
- **Linear spring**
- **Nonlinear spring + angular falloff**



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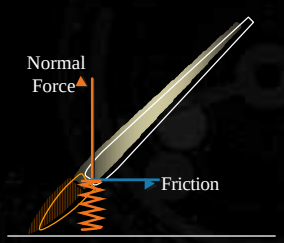
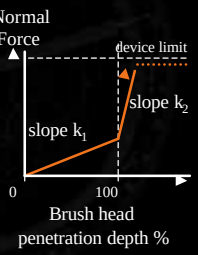
Haptics – Linear





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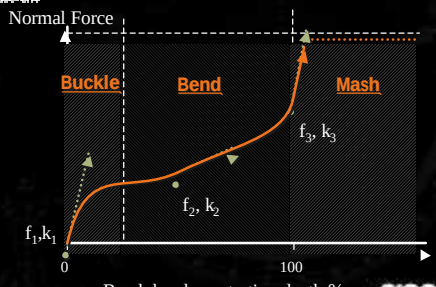
Haptics – Non-linear (Spline)



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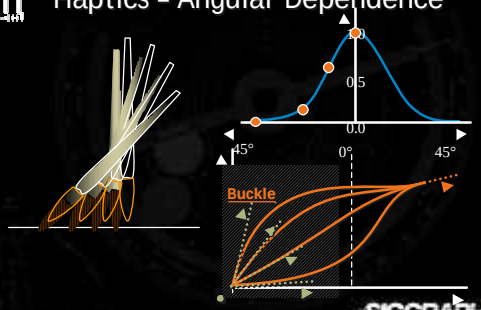
Haptics – Angular Dependence



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System Components

- **Brush Model**
- **Haptic Model**
- **Paint Model**

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Paint Simulation

- **Interactive**
- **Oil/Acrylic paint**
- **Take advantage of 3D Brush**

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Paint Transfer

FLASH ANIMATION

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Paint Effects

- [video]
- Bi-directional paint transfer
- Glazing wet paint over dry
- Variable wetness

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Paint Effects

- Paint volume recorded
- Hardware accelerated

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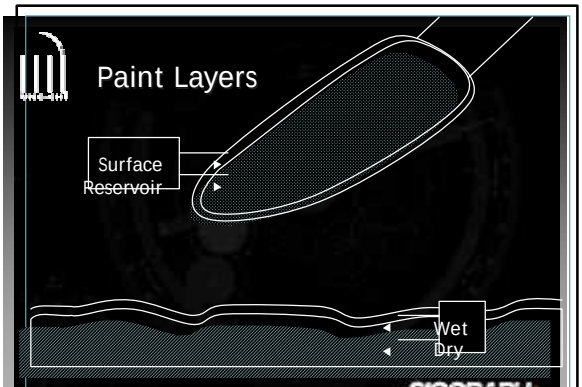
Paint Layers



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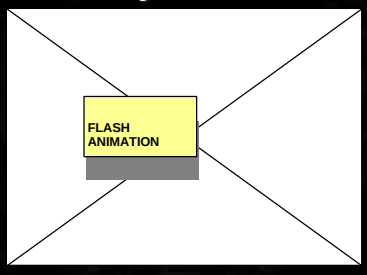
Paint Blending



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Paint Rendering

- **Alpha blend wet over dry**
- **Embossing of paint volume**

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Frog
• Rebecca Holmberg
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1.3
• James Ball
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The Old Well
• Rebecca Holmberg
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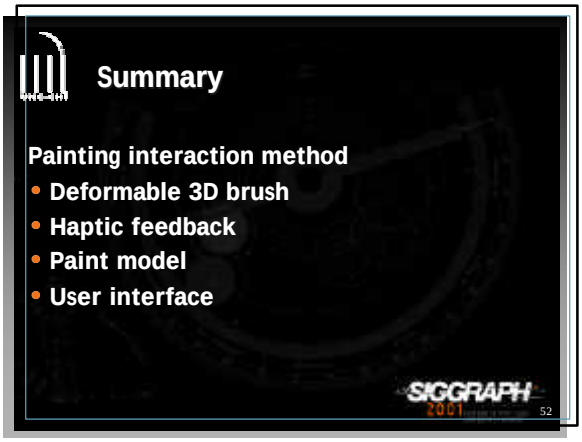
Summary
Painting interaction method
• Deformable 3D brush
• Haptic feedback
• Paint model
• User interface
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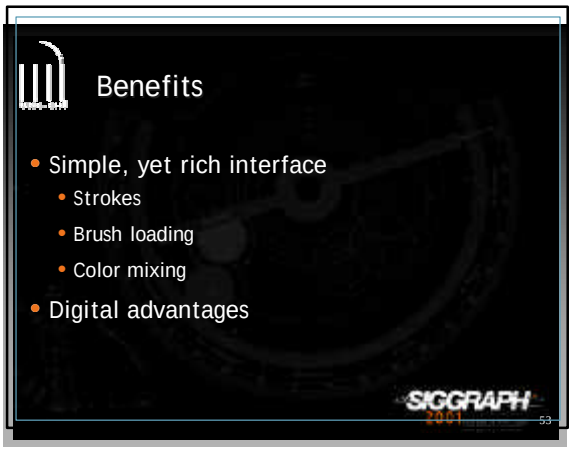
Benefits
• Simple, yet rich interface
• Strokes
• Brush loading
• Color mixing
• Digital advantages
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Future Work
• Improvements to brushes, haptics, paint
• Painting on 3D models
• Training & Studies
• Other artistic tools / haptic tools
• Formal user studies
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Acknowledgements

- **Artists**
  - Rebecca Holmberg (special thanks)
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  - James Ball
  - Eriko Baxter
  - Sarah Hoff
  - Andrei State

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Acknowledgements

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  - Army Research Office
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  - Intel
  - National Science Foundation
  - Office of Naval Research

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Slide Show & Questions

- Gallery

See dAb in action!
Try it for yourself!
***TODAY* @ the CAL**
from 2-4pm

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Partial Drying

$$C'_{dry} = \frac{a \cdot C_{wet} + (1-a) \cdot C_{dry} - a' \cdot C_{wet}}{(1-a')}; \quad a' = a - da.$$

Where :

C_{wet}, C_{dry} are wet & dry color

a, da are wet paint volume & removed volume

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dAb, the happy medium

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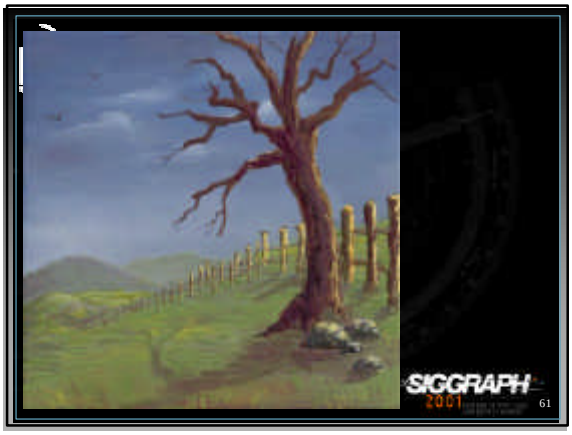
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Harbor
Rebecca Holmberg
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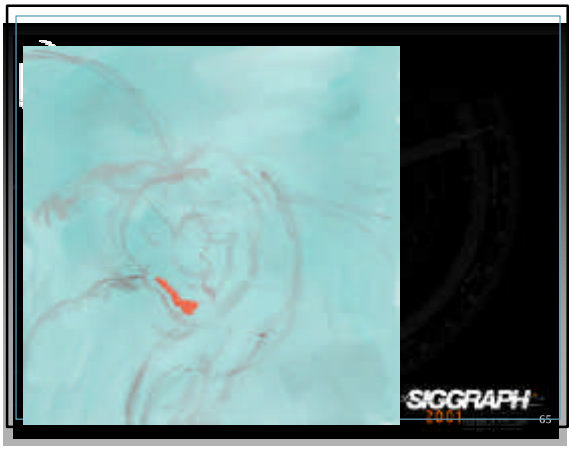
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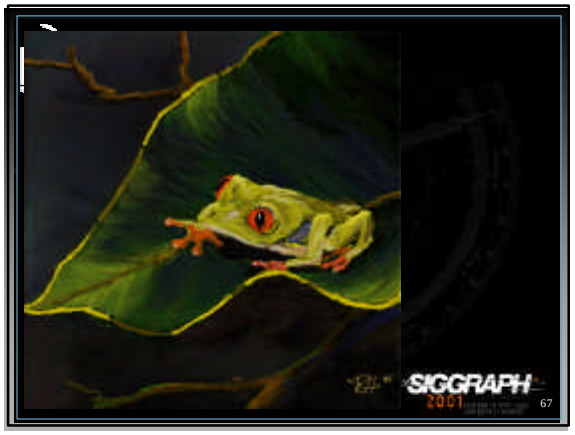
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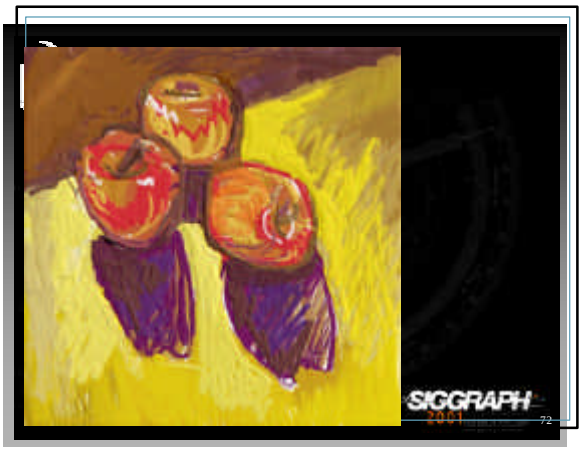
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Ominous
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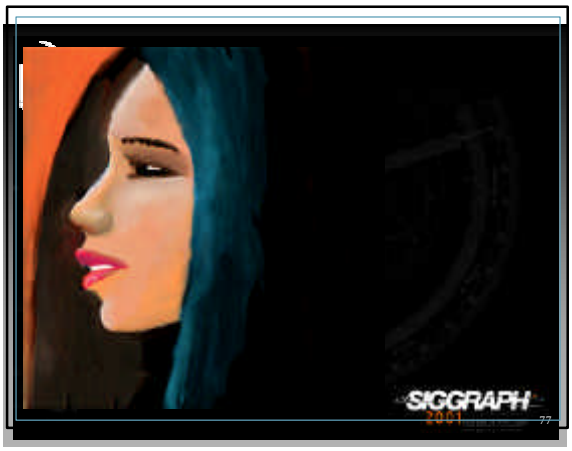
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